Herbert Hoover Dike: Past, Present and Future

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President’s Message

I hope you all had a relaxing and enjoyable holiday with friends and family, and your year is off to a great start. It is hard to believe March is here already and our annual meeting in Miami is less than two months away. It is shaping up to be the most successful conference yet. Christina Winkler and her Planning Committee have done a great job putting together a very impressive program full of rich technical content and enjoyable activities to make sure the conference is a success. As the anchor of our Educate Imperative, the conference continues to allow members to exchange ideas, learn from one another, and make new relationships through the vast network that is our community of practice. Thank you everyone who submitted abstracts; we look forward to your presentations during the conference.

I think most of you know that we have a new Executive Director, Sharon Powers, who started last November. In keeping with the Cultivate Imperative of our Strategic Plan and the goal of continuing to manage the front office of USSD, Sharon has been very busy getting to know the organization, moving out of the old office space in Denver into an office in Westminster, setting up financial systems, establishing access to our various financial accounts and reconnecting with vendors and partners in the industry. This has been more than a full-time effort and there is still a lot of work to do, but Sharon seems undeterred. If you have not had an opportunity to meet Sharon yet or speak to her by phone or email, please introduce yourself at the conference.

As part of our Collaborate Imperative, USSD seeks to engage with other organizations to jointly advance the state-of-practice. During the ICOLD 2017 meeting in Prague, Mike Rogers, John Wolfhope and I met with representatives from the Korean Nation Committee (KNCOLD) and representatives from the Canadian Dam Association (CDA) to sign letters of intent to develop partnering agreements between our three organizations. That initiative continues to advance, having supported each other with delegates at our respective annual conferences. In addition, during ICOLD 2018 in Vienna this summer, we will meet with members of INCA (ICOLD National Committees of the Americas) to discuss collaborative initiatives, including the next Dam Safety in the Americas International Workshop, to be held in Paraguay during 2019. In addition, we are looking forward to welcoming leaders from most of the INCA member countries this year at our conference in Miami. We are also currently planning fall technical workshops for 2018 and 2019, and are evaluating collaborative opportunities with FEMA and the International Association for Hydro-Environment Engineering and Research (IAHR).

Our Advocate Imperative is being addressed in a number of ways. The Board recently approved the charter and leaders for the new USSD Committee on Advocacy, Communication and Public Awareness (ACPA). Kelly Schaeffer, chair of the USSD Committee on Environment and Sustainability has provided a response to an article, Facing the Challenges of Dam Removal in Alaska, by Brad Meiklejohn, Alaska State Director of the Conservation Fund (see page 16). Both articles provide thought-provoking perspectives on the challenges of dam removal and the role of our water infrastructure in the future, and I encourage you to read them.

Thank you for your continued support of USSD. I look forward to 2018 and continuing to work with all of you to strengthen the community of practice and enhance our collective commitment to dam and levee safety.

Dean B. Durkee
President, USSD

The USSD Newsletter is now Dams and Levees, Bulletin of the United States Society on Dams.

The new name more accurately reflects the technical and professional content of the publication.
Excitement is brewing for the USSD 2018 Annual Conference and Exhibition, the first to be held in the state of Florida. A record 225 abstracts were submitted in response to the Call for Papers, and nearly 200 presentations will be featured during six concurrent technical sessions and the poster session. The 75-booth exhibition sold out in two months. The Host for the 2018 Conference and Exhibition is the U.S. Army Corps of Engineers, Jacksonville District.

The 2018 USSD Conference Theme is A Balancing Act: Dams, Levees and Ecosystems. The theme is particularly relevant this year, with the Conference being held in Miami. The theme represents some of the unique challenges that coastal environments and delicate ecosystems face, which requires balancing the purposes of dams and levees with environmental, social and economic interests.

Technical Program
The strong response to the Call for Papers has resulted in an outstanding technical program. The Conference Planning Committee, chaired by Christina Winkler, has developed a program that will feature six concurrent sessions that include both 15-30 minute oral presentations, as well as shorter, highly focused 8-10 minute presentations. A Plenary Session on Tuesday morning will include invited presentations addressing contemporary issues. Participants will have more than 200 presentations to choose from!

Networking
Opportunities for networking and socializing will be held throughout the week. In addition to lunches and receptions, conference attendees can look forward to an outdoor riverfront party on Tuesday evening, and an evening at the ballpark to watch the Miami Marlins play the Philadelphia Phillies in a private party area.

Sponsorships
Visit the conference website to see the sponsorship program and current sponsors.

Field Tours
Two field tours, organized by the Corps of Engineers, will be featured during the conference. A half-day tour on Thursday afternoon will visit the Tamiami Trail, part of the Florida Everglades restoration project to enhance water conveyance to the Everglades National Park. The day-long Friday tour will feature the Herbert Hoover Dike, a 143-mile-long earthen dam that surrounds Lake Okeechobee, the heart of the Everglades system. Various construction projects designed to reduce the risk of catastrophic failure of the aging structure are ongoing.

Workshops
Several concurrent workshops, organized by USSD Technical Committees, will be held on Thursday.

- Everglades Restoration (morning only).
- Words Hold Water – Raising the Communication Bar in the Dams and Levees Industry (morning only).
- Evaluation of Numerical Models and Input Parameters in the Analysis of Concrete Dams
- Construction of Slurry Walls for Levees and Small Embankment Dams
- Cutting-Edge Rapid Flood Modeling: Hands-on with DSS-WISE™ Light
- Case Histories in Dam Safety Risk-Informed Decision Making

5K FUNds Run/Walk
The fourth annual 5K FUNds Run/Walk to support the USSD Scholarship Fund will be held on Wednesday, May 2. Contribute a minimum of $250 to the USSD Scholarship Fund and your logo/name will be displayed as a 5K sponsor on the publicity poster.

Conference website:
https://ussdams.wildapricot.org/event-2471270
Mark Your Calendars: USSD 2019 Slated for Chicago

The 39th USSD Annual Conference and Exhibition will take place in Chicago, April 8-12. The beautiful downtown Chicago Hilton will be the conference venue for all events.

Rachael Bisnett, Stantec, will be the conference chair. Look for an invitation soon to join the planning committee, which will meet in Chicago August 14 and 15 to review submitted abstracts and develop the conference technical program.

The Call for Papers will be issued in early June. Plan now to submit an abstract.

Public Safety Workshop

USSD will present a Workshop on Public Safety and Security for Dams, tentatively scheduled to take place in Fairfax, Virginia, during October 2018.

William Foos and Paul Schweiger of Gannett Fleming will be the lead instructors. Topics addressed during the Workshop will include:

- Legal Responsibilities
- Policy, Plans and Procedures
- Security Program and Assessment
- Dam Vulnerabilities and Public Hazards Analysis
- All Hazards Risk Assessment
- Risk Treatment Solutions
- Physical Security and Public Safety Measures

Additional details will be available on the USSD website soon.

Photo courtesy of Choose Chicago.

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Our clients face tough decisions with limited resources. That’s why we support leading water associations—like USSD—to help make great things possible for our industry.
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Overview and History

The Herbert Hoover Dike (HHD) is an earthen embankment system located along the perimeter of Lake Okeechobee in south, central Florida. The Lake Okeechobee drainage system is comprised of 1,800 miles of canals and levees and 160 major drainage basins. At the center of the watershed is Lake Okeechobee and the dike. The lake covers 730 square miles and receives its inflow principally from a 5,600 square-mile drainage basin. Today more than six million people in 16 counties depend on some aspect of this system, with that number expected to double by 2050.

Lake Okeechobee is a shallow lake with a natural water surface elevation between 10.7 and 16.7 feet NAVD88. The lake is located at the south end of the Kissimmee River, which is the main source of inflow to the lake. The lake is also at the north end of the historical Everglades, which was the traditional outlet for excess water prior to human involvement at the project. The historical Everglades began at the south end of Lake Okeechobee and extended from the lake to the southern tip of the Florida mainland.

Historically, water entered the lake from the north and spilled excess water over the south bank of the lake into the northern edges of the Everglades. In a swath 40 miles wide and 100 miles long, water from the lake would sheet flow over a trough of limestone and peat and ultimately into the ocean. East of the trough was a narrow coastal ridge, between 5 and 10 miles wide, that now contains the region’s largest coastal cities (Miami and Fort Lauderdale). West of the Everglades is a sandy area up to 23.7 feet NAVD88. In the years since 1900, various improvements have greatly reduced the size of the Everglades, which is now located at the very bottom of mainland Florida.

Today, Lake Okeechobee and the Everglades is an artificially altered environment. The ground surface around the lake generally slopes downward to the south and east. The lowest elevations are to the south in the historic everglades area where the ground surface generally ranges from about 8.7 to 13.7 feet NAVD88 and is typically covered with a surficial layer of peat overlying limestone deposits. Sand ridges are found on the northeast and northwest sides of the lake with elevations generally ranging from about 13.7 to 18.7 feet NAVD88.

Inflows to the lake mostly come from the Kissimmee basin which stretches from the northern limits of the lake up into central Florida. Inflows feed the lake through several rivers/canals, the largest of which is the Kissimmee River which flowed unregulated into Lake Okeechobee until the 1960s. Other sources include Taylor Creek at the northern tip of the lake and Indian Prairie Canal and Harvey Pond Canal on the northwest side of the lake. Fisheating Creek to the west also feeds the lake and remains the only unregulated inflow source.

Water exits Lake Okeechobee through control structures at six major canals/waterways. Most of the discharge flows either west through C-43 to the
Caloosahatchee River and the Gulf of Mexico, or east through C-44 to the St. Lucie River and the Atlantic Ocean. Lesser amounts discharge into Stormwater Treatment Areas (STAs) and then sequentially through the three Water Conservation Areas (WCAs) to the south and southeast. Confined by levees, the combined areas of WCA 1, 2, and 3 are almost twice that of Lake Okeechobee itself. During wet periods, freshwater is released from WCA 3 to Everglades National Park; while at the same time excess storm water is pumped from the canals into WCAs and the lake to relieve flooding. During dry periods, water is released from Lake Okeechobee to the Everglades Agricultural Area (EAA) that lies between the lake and the WCAs. Water from Lake Okeechobee and the WCAs is also released to Everglades National Park to meet minimum flow requirements, as well as into the canals where it helps replenish groundwater levels in the Biscayne aquifer.

Local construction in Lake Okeechobee began in 1884 with the first channel being dredged from Lake Okeechobee to the headwater of the Caloosahatchee River to provide access to the Lake. The channel was improved several times between 1906 and 1935 with the Federal Government doing the last improvement. Starting around 1900, farmers started cultivating crops in the area south of Lake Okeechobee. These areas were rich peat lands that needed improved drainage systems to provide effective at farming. Four major drainage canals were started in 1906 by the newly formed Everglades Drainage District and were constructed over the next 23 years as funds became available. Starting in 1906 through 1910, 11.2 miles of the North New River Canal and 4.2 miles of the Miami Canal were dredged. By 1913 those canals had been completed to the ocean and work had started on the West Palm Beach Canal. Additional portions of the Hillsboro Canal had also been constructed to allow water from Lake Okeechobee to drain into the Everglades. These canals were only partially successful at providing adequate drainage for the areas south of the lake. Discharge was primarily in place for only low flow storm events.

In response to low lying areas around the lake being constantly flooded, the residents starting dredging the St. Lucie Canal in 1916 to reduce this hazard. Completion of the St. Lucie Canal occurred in 1924 but the canal remained ineffective because of sedimentation issues (bars forming) in the canal from hurricanes in 1924 and 1926. The canal became effective after 1926 when the sedimentation bars were removed.

By the late 1920s, there were six major canals that left Lake Okeechobee for the coast, comprising a total of 440 miles of channel. They included the Caloosahatchee River and Three Mile Canal on the Gulf of Mexico side; the Miami Canal, North New River Canal, Hillsboro Canal, West Palm Beach Canal, and St. Lucie Canal on the Atlantic side. In addition, there were other minor canals and lateral canals that formed connections between the major canals. Most of this work was done by the Everglades Drainage District by the end of the 1920s. Completed work also included 47 miles of levees and 16 locks.

The first serious settlements along the south shore of Lake Okeechobee began around 1910, with the development of the R. J. Bolles Hotel on Ritta Island. By 1915, the first town, Moore Haven, was established along the shore of Lake Okeechobee at the north end of Three Mile Canal. Started by James A. Moore, it became a thriving farm community. After the railroad came, three years later, a fishing industry developed, capitalizing on local streams and Lake Okeechobee. Clewiston had its beginnings about the same time but not under that name. Originally known as Sand Point, it was located about 12 miles east of Moore Haven. The first local farmers found the soil to be rich, but agriculture was hampered by frequent water problems that ranged from flooding to drought and peat fires. Between 1910 and 1920, local interests constructed the first levees built along the lake’s perimeter under the Everglades Drainage District programs. The levees extended for about 47 miles along the south shore between Bacom Point and Moore Haven. On the north shore, a short levee section was constructed just north of the lake’s confluence with the Kissimmee River. These initial levees were composed largely of mud, sand, shell, and marl taken/excavated from adjacent borrow canals. The levees ranged from 5 to 8 feet in height, and were definitely not designed for hurricane storms. Levee crest elevations typically ranged from 19.7 to 25.7 feet NAVD88.

Since 1910, Florida had not experienced a large hurricane that affected the Lake Okeechobee area. In 1926 and 1928, the Lake Okeechobee area was subjected to several devastating hurricanes. Those storms produced wind-induced surge conditions on the lake and in some locations the existing levees were overtopped. The storms claimed an estimated 3,000 lives. These catastrophes demonstrated that the original levees built by local interests were not adequate, and prompted Federal involvement in the provision of flood protection.

The Rivers and Harbor Acts of 1930 and 1935 were the first Congressional Authorizations for HHD and led to the construction of the 67.8-mile long south shore dike that was completed in 1936 and the 15.7-mile long north shore dike that was completed in
1938. The average crown elevation (31.2 feet NA VD88) of the finished dike rose about 17-18 feet above the adjacent land elevation. The original 1930s construction utilized hydraulic fill techniques and/or dragline excavation and placement methods. In addition to the levee construction, several culverts with control gates and six hurricane gates were installed to assist with the flood control component.

The creation of the HHD was the physical sign of the government’s resolve to protect the region from lake floods. As a result, local settlements continued to grow, draining the land as they went and altering the natural hydrology of the region. This development was also spurred by general dry conditions in southern Florida from 1931 to 1945, which led to a great expansion of agricultural lands. Also, land which in the past had regularly flooded was now drying out and subsiding. South Florida experienced extremely dry conditions between 1931 and 1945. As a result, groundwater levels decreased and saltwater intrusion of municipal water supply wells was experienced in Miami and other coastal cities. The dry conditions sparked fires which claimed thousands of acres of peat soil in the Everglades. During these dry years, Floridians realized that future water management efforts must consider not only drainage and flood control, but water conservation as well.

In 1947, the drought ceased as 100 inches of rain fell on south Florida. Three tropical cyclones inundated the Lake Okeechobee area between September 17 and October 12, 1947. Storm surge on Lake Okeechobee was as great as six feet along the south shore, which resulted in a short-duration, peak lake stage. However, the dike performed well and there was no surge-induced flooding or loss of life. This series of extreme drought and flood events prompted the Corps of Engineers to formulate a comprehensive water management program for South Florida. That program, the Central and Southern Florida (C&SF) Project, was authorized by the Flood Control Act of June 30, 1948. Its purposes included flood prevention, navigation, water level control, water conservation, prevention of saltwater intrusion, and fish and wildlife preservation.

The design and construction of C&SF Project improvements related to Herbert Hoover Dike were accomplished in the 1950s and 1960s. The dike system today encircles Lake Okeechobee entirely, except in the vicinity of Fisheating Creek on the western shore where the embankment ties back into higher ground surface elevations. In addition, tieback levees from HHD extend several miles up the Kissimmee River, Indian Prairie Canal, and Harvey Pond Canal where it ties into inflow spillways that control the canals. The HHD embankments total about 143 miles in length with crest elevations ranging from as low as 27 feet on some of the tiebacks to as high as 45 feet, NA VD88. Lakeside embankment slopes vary from 1V:3H to 1V:10H and landside slopes range from 1V:2H to 1V:5H.

**Major Rehabilitation and Evaluation Report**

In 2000, USACE completed a Major Rehabilitation and Evaluation Report (MRR) for the dike to address problems related to internal erosion and structural stability of the HHD system documented since 1984. Due to the extensive length of the dike system, and the variability of conditions that exist along its length, the study area was divided into 8 separate sections (reaches) to better define the conditions that exist along the levee. Reaches 1 through 8 were established to prioritize the rehabilitation efforts. HHD as part of a USACE-wide dam screening for portfolio risk assessment effort was assigned a Dam Safety Action Classification (DSAC) of 1 in 2006 due to the urgency of repairs needed and the high consequences of a potential dam
failure, and rehabilitation began.

In Reach 1 (highest priority for rehabilitation), between S-308 at Port Mayaca and S-351 at Belle Glade (approximately 22 miles), a seepage cutoff wall was constructed between 2007 and 2012. Four “gap” locations within the 22 miles of cutoff wall at existing structures that do not require rehabilitation construction will be jet grouted in 2018 to complete the 22-mile-long seepage barrier. The construction of an additional 6.8-mile cutoff wall between S-351 at Belle Glade and S-354 at Lake Harbor (Reach 3, aka Reach 1 extension) will begin in 2018 and should be completed by 2020.

Interim Risk Reduction Measures

Near the start of rehabilitation construction, USACE developed and implemented interim risk reduction measures (IRRMs) to be in place until dike rehabilitation was complete. The IRRMs included both one-time actions and reoccurring activities. Examples of IRRMs conducted were downstream toe ditch and quarry backfilling, interior riprap protection placement, emergency material stockpile placement, updated surveillance plan for increased inspections, and a lowered lake level regulation schedule.

In addition to cutoff wall construction, the age and structural deterioration of the 1930s and 1960s culverts, 32 Federal O&M gated culverts in total, were determined to present a significant risk due to a high probability of failure, primarily related to collapsing of the culvert or seepage along the conduit and/or seepage into the conduit. The historic steel corrugated metal pipe (CMP) structures are being replaced with state of the art cast-in-place barrels with soil bentonite cutoff walls, and chimney and blanket drain seepage collection systems. Removal, replacement, or abandonment of these structures started in 2011, and is scheduled for completion in 2022.

Cutoff Wall Construction

A cutoff wall was determined to be the most efficient and technically acceptable risk reduction solution to remediate areas of HHD that were identified as having intolerable internal erosion risk. The proposed cutoff wall location would be a 2-foot-wide soil cement bentonite wall along the approximate centerline of the embankment, with temporary construction platforms needed to widen the crest for the duration of construction. A total of 27.3 miles of additional cutoff wall will be constructed. The cutoff wall construction will span from just west of Lake Harbor (continuing from the Reach 3/Reach 1 extension) to just east of Moore Haven in CIZ-B (Reach 2 and a portion of Reach 4). Cutoff wall will also be constructed for a portion of CIZ-C (Reach 6A) near Lakeport. In addition to the cutoff wall, floodwalls and embankment armoring will be required at three locations where the embankment is low and susceptible to overwash or overtopping. These locations include the embankment adjacent to S-71 (CIZ-C and CIZ-D) located...
on the Harney Pond Canal, the embankment adjacent to S-72 (CIZ-D and CIZ-E) located on the Indian Prairie Canal, and the embankment at the intersection of the SR-78 bridge and Harney Pond Canal (CIZ-C and CIZ-D). The S-71 and S-72 structures are nearly identical in design and construction and are the terminus of HHD to the north. At these locations, the HHD earthen embankment drops down in elevation to meet the service platform of each structure. A floodwall ranging in height from one to seven feet will be constructed adjacent to these structures. A similar situation occurs at the intersection of SR-78 Bridge and Harney Pond Canal. The embankment drops down in elevation to meet the bridge abutment. Armoring the embankment at the intersection of the bridge at the SR-78 and Harney Pond Canal with articulated concrete block matting is required. The following figure illustrates the remaining cutoff wall, jet grouting, floodwall, and armoring to be constructed.

**Conclusion**

After completion (currently estimated in 2025) of the rehabilitation construction activities for the Herbert Hoover Dike, USACE will complete post-implementation evaluations of the project per CIZ. At that time, the Dam Safety Action Classification will be revisited and it will be determined if there are still requirements to maintain Interim Risk Reduction Measures. A study for a new regulation schedule could be undertaken concurrently while risk reduction features are constructed. Implementation of any new regulation schedule will depend on the magnitude and associated effects resulting from a change to the current Lake Okeechobee Regulation Schedule and is expected to occur near the end of the rehabilitation construction activities.
Stantec is proud to be supporting California DWR on the Oroville Dam Spillway Response and Recovery Team.

Photo courtesy of the California Department of Water Resources

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Advocacy, Communication and Public Awareness

Keith Ferguson, Committee Chair

The USSD Board of Directors recently approved the establishment of a USSD Committee on Advocacy, Communication and Public Awareness (ACPA). The Committee replaces three USSD Committees: Advocacy, Communication (formerly Newsletter), and Public Awareness.

The new Committee includes three subcommittees with separate charters: Advocacy and Public Awareness; Communication; and Website and Social Media. Each subcommittee will have a chair, vice chair and YP vice chair; and the chairs of the three subcommittees will rotate as chair of the full Committee.

Subcommittee Chairs
The Board approved the following appointments:

Advocacy and Public Awareness — Keith Ferguson, Chair; Rebecca Ragon, Vice Chair
Communication — Phoebe Percell, Chair; Bruce Rogers, Vice Chair; Lan Nguyen, YP Vice Chair
Website and Social Media — Stuart Harris, Chair; Yulia Zakrevskaya, Vice Chair

Charter
According to its charter, the Committee will serve as the clearinghouse for establishing positions on technical and policy related issues, messaging and communication for USSD. The Committee will work on behalf of the Board of Directors, the Executive Committee, and the general membership for initiatives to:

1. Support national, state and local programs related to dams, levees, and stewardship of water resources.
2. Support legislation and funding of local, state and federal programs.
3. Educate, by proactively addressing the full set of dam/levee issues and needs, and providing information on the role of dams in the management of water resources to benefit society and the natural environment.
4. Develop common messaging for internal communication with members and external communication with other associations and trade organizations, congressional inquiries, and the public.
5. Advance USSD’s use of communication resources to interact with members and a broad range of people including electronic distributions, social media, and print and visual media.
6. Socialize advocacy, public awareness, and technical developments within and outside USSD through the printed publication of Dams and Levees, Bulletin of the U.S. Society on Dams; electronic communications; workshops and keynote presentations and proceedings from annual conferences.
7. Develop and evaluate measurements of success for USSD’s strategic Advocacy Imperative.

Position Statements
At the direction of the Board of Directors, ACPA will develop a process for USSD position statements. Generally, position statements will first be drafted by the technical committees. ACPA will conduct a thorough review, consulting professionals both inside and outside of USSD. ACPA will then submit a recommendation to the Board for approval.

Hydraulics and Hydrology

Gregory Paxson, Committee Chair

Name Change and Vice Chair
At the recommendation of the Committee, the USSD Board recently approved changing the name from Hydraulics of Dams to Hydraulics and Hydrology. Keil Neff was approved as Committee Vice Chair.

Position Statement on Sustainable Reservoir Management
The Committee prepared a position statement on Sustainable Reservoir Management, which was approved by the USSD Board of Directors during their November 2017 meeting. The position statement encourages dam owners to develop sustainable reservoir sediment management plans for the reservoirs that they own or manage by 2030.

The position statement follows a similar policy for Federal dams. In August of 2014, the Federal Advisory Committee on Water Information (ACWI) approved a resolution prepared by the Subcommittee on Sedimentation that encourages all Federal agencies to develop long-term reservoir sediment-management plans for the reservoirs that they own or manage by 2030 that would include either the implementation of sustainable sediment-management practices or eventual retirement of the reservoir. As a leader in the dam engineering industry, USSD’s opinion carries weight among dam owners. Building off of the ACWI Resolution, USSD prepared this policy to encourage this forward thinking on sustainability to all dams, not just those owned by the Federal government.

The full position statement can be accessed from the USSD website under the Mission tab (www.ussdams.org/about/mission/).

2018 Conference
The Committee has organized five technical sessions for the upcoming USSD Conference in Miami:

2A: Reservoir Sediment Management
3F: Calibration and Validation - Panel Discussion
4B: Dam Break and Reservoir Modeling
5B: Spillway Modeling
6B: Big Floods and Spillways
Overcoming Challenges with Innovative Solutions
The Conservation Fund has nearly completed the demolition of the long-abandoned Lower Eklutna Dam, near the native village of Eklutna, Alaska. The Lower Eklutna River Dam Removal Project is the most ambitious river restoration project ever attempted in Alaska.

The Lower Eklutna Dam was built in 1928 as part of Alaska’s first hydroelectric project. Located in a dramatic 400-foot deep canyon, access to the dam site was a severe challenge during the construction (and demolition) of the dam. In construction, a tram cart delivered concrete down the cliff face to the workers below. This hardy crew worked throughout an entire Alaskan winter to complete the dam in a year’s time.

The dam itself was a concrete arch whose dimensions were 70 feet wide, 100 feet tall and 9 feet thick at the dam base. This structure pooled and diverted water through a half-mile tunnel to a generating station nearby. Power ran by wire twenty miles south to Anchorage, providing the first reliable supply of electricity to this frontier settlement. The Lower Eklutna power project operated until the early 1950s when it was decommissioned and ultimately abandoned. Ownership of the dam remained in limbo until settlement of the Alaska Natives Claims Settlement Act conveyed the dam and all the surrounding land to the Eklutna Village Native Corporation.

The Eklutna River was once a prolific salmon-producing river that supported the Eklutna Dena’ina people, who located their village on Cook Inlet’s Knik Arm near the mouth of the Eklutna River. Although the Native Eklutna people are still there, the salmon are greatly diminished, due to a succession of water diversions and hydropower projects which cut off water flow and fish passage in the Eklutna River. Repeated studies over several decades have recommended the removal of the Lower Eklutna Dam as an essential first step in restoring the Eklutna River.
Despite being decommissioned in the 1950s, the Lower Eklutna Dam survived the 1964 Alaska Earthquake (magnitude 8.2) with no signs of impairment. Though the dam remained structurally sound and showed no imminent signs of failure, the State of Alaska Office of Dam Safety had long-recommended its orderly removal. Because the structure was an orphaned, unmaintained dam upstream of three bridges, a major highway and a railroad, there was significant public safety benefit to removing the dam in a controlled manner rather than waiting for its ultimate failure.

Removing the Lower Eklutna Dam is the first step in a multi-phase restoration plan for the Eklutna River. The principal conservation outcomes that will result from removing the Lower Eklutna Dam are:

- Restore fish passage to a seven-mile reach of the Eklutna River.
- Improve spawning habitat in the lower Eklutna River for five species of salmon and Dolly Varden.
- Re-establish natural river functions in the lower Eklutna River.
- Re-establish habitat connectivity for fish and wildlife on the lower Eklutna River.
- Take a major step towards the recovery of the entire Eklutna River watershed.

While discussed for decades, The Conservation Fund began to actively pursue the dam removal in 2014. After identifying key partners, in collaboration with Eklutna Inc. (the Eklutna Native village corporation and landowner) and HDR (primary technical consultants for the project), the Fund initiated project scoping, baseline research, and assessment of construction methodologies in 2015. With necessary permits secured in 2016, site preparation was completed in fall of 2016. The 2017 work season saw the removal of 90% of the dam structure, the remainder of which should be entirely removed in the Spring of 2018. Site remediation and sediment management will continue in 2020. Negotiations for the restoration of in-stream flows and monitoring of spawning, turbidity and sediment transport will continue into 2020 and beyond.

Funding for the $7.5 million project was provided largely by The Conservation Fund, with additional financial support from the Rasmuson Foundation, the M.J Murdock Charitable Trust, the National Fish and Wildlife Foundation, the Open Rivers Fund of the Hewlett Foundation, Resources Legacy Fund, the Marnell Corporation, the Alaska Sustainable Salmon Fund, Patagonia, Orvis, Wells Fargo and the Alaska Community Foundation.

Where most major dam removals take decades to complete, this project has gone from concept to near-completion in only three years. The rapid advancement of the project is due in large part to the fact that most of the money came from private sources, short circuiting the lengthy delays that inevitably come with government funding. With a backlog of thousands of deadbeat dams that are slated for removal across the nation, this project serves as a model of efficiency and cost-effectiveness.

In addition to the funding challenges, there were severe technical challenges to the project. The Lower Eklutna Dam is located in a 400-foot deep canyon with sheer walls and no road access. Accessing the dam involved the installation of the state's largest crane with a 400-foot reach and construction of a dramatic 500-step aluminum staircase.
into the canyon. An additional complication was working on and around the 70-foot-deep accumulation of 300,000 cubic yards of silt, sand, and gravel that had built up behind the dam following its abandonment in 1955. Combined with the tight confines of the canyon, these unstable and dynamic sediments required caution and creativity.

Concerns for the downstream infrastructure ruled out blasting the dam. Instead, a combination of fracturing with expansive grout and hammering with pneumatic jackhammers was used to break the dam down into bite-sized chunks. Sediment management techniques included 10-foot by 20-foot polycarbonate “tundra mats” to keep the machinery out of the LaBrea-tar like muck and a hydraulic mining monitor to move the sediment away from the work area.

Removing the Lower Eklutna Dam has already provided significant economic benefits by creating over thirty jobs in construction, research and project management for Native Alaskans through the partnership with the Native Village of Eklutna and the Eklutna Native Corporation. Additional benefits to all Alaskans include the recovery of Cook Inlet king salmon and the potential restoration of a major sockeye salmon run just 30 minutes from Anchorage. Restored salmon runs will also help the endangered Beluga Whale with additional forage fish sources.

Although removal of the Lower Eklutna Dam will not by itself rebuild salmon runs to their historical levels, the mere presence of the dam has thwarted any other restoration efforts. The main limiting factor for salmon in the Eklutna River is very low water due to hydropower diversions. The Eklutna Power Project, a federal project further up the watershed from the Lower Eklutna Dam, diverts 90 percent of the water out of the Eklutna watershed into a tunnel that services a powerhouse located on the Knik River. The power producers, a consortium of three utilities, have long argued that releasing water into the Eklutna River is pointless as long as the lower dam remains in place.

Complete recovery of the Eklutna River will depend on the restoration of water flows back into the Eklutna River. The Eklutna Power Project is authorized under the 1991 Eklutna-Snettisham Agreement, which requires the Eklutna Power Project operators to initiate mitigation for their impacts to fish and wildlife no later than 2022. The state and federal regulatory agencies that have jurisdiction over the Eklutna Power project have taken the view that sufficient water flows must be restored to the Eklutna River to mitigate for 88 years of water diversions. Taking all the water out of a salmon-bearing river is no longer an acceptable practice.

Beyond the significant conservation benefits that will result from removing the Lower Eklutna Dam, this project has greater symbolism. One reason Alaska still has abundant salmon is because we have mostly avoided the mistake of building dams on salmon-bearing rivers. At the Eklutna River, Alaskans are recognizing the problems created by an ill-considered dam and are collaborating to fix those problems. We hope this project will be a constant reminder to Alaskans that salmon and dams are generally incompatible.
Leading by Example: Collaboration and Rigorous Science Required to Address Changing Needs

Kelly Schaeffer, Principal, Kleinschmidt; and Chair, USSD Committee on Environment and Sustainability (kelly.schaeffer@kleinschmidtgroup.com)

Editor’s note: The following is a response to the article by Brad Meiklejohn that begins on page 16. The views expressed are those of the author and do not necessarily reflect the view of USSD.

Brad Meiklejohn’s article highlighting the challenges of the Lower Eklutna Dam removal in Alaska raises some important issues around the multitude of purposes dams have held over time; the economic, engineering, and environmental sustainability of our water infrastructure; and the role that collaboration and partnership serve in solving problems on our nation’s waterways.

I commend the U.S. Society on Dams for publishing Mr. Meiklejohn’s article. As stated in its strategic plan, USSD has four imperatives that inform its mission: Advocate | Educate | Collaborate | Cultivate. To accomplish its mission, USSD must take a leading role in 1) exchanging ideas; 2) providing thought leadership and technical expertise; and 3) leading by example when we engage in existing projects and in future projects initiated in this country’s new era of infrastructure development.

These roles are not easily undertaken. There are numerous challenges, made more complex by myriad interests, “looking in the rear-view mirror,” and attempting to integrate these failures and successes of our past into lessons learned. For example, while we don’t dismiss the Lower Eklutna dam’s effect on salmonid populations, we also know that many of our water infrastructure projects built in the late 1800s through the 1930s, like the Lower Eklutna, were developed to meet critical public needs including flood control, navigation support, water supply, and electricity. Anchorage was in a time of frontier settlement and in search of its environment. Discussions between the two organizations culminated in a 2017 Memorandum of Understanding. Like the Lower Eklutna dam removal process, USSD and TNC seek to discover common interests and then lead the technical experts toward resolution.

Second, we insist upon and support rigorous science in the design, engineering and construction of water infrastructure projects. We know significantly more today about the effects of infrastructure on the environment through the evolution of data collection methods and the body of quantitative and qualitative data. Armed with this knowledge, we can enhance the design, engineering and construction methods to consider the many interests involved in protecting the environments associated with our water infrastructure projects.

Finally, we lead by example. The Lower Eklutna case study highlights the chronic national issue of abandoned and obsolete infrastructure — that is, those projects that no longer serve their project purpose. Mr. Meiklejohn raises one solution to this issue through the concept of private/public partnerships. Developing these funding options is critical to moving projects forward, whether it be dam removal — as in the case of the Lower Eklutna dam — to a full/partial rehabilitation or repurposing of an existing dam or levee. It is incumbent on us through our technical expertise and leadership to think creatively about the potential for meeting multiple objectives with projects, and to encourage agencies, private partners, and non-governmental organizations with overlapping interests to participate.

What is clear, is that our societal needs today are different than they were 100 years ago — as are the range of values that we aim to satisfy when weighing the alternatives to meet those needs. Applying the lessons learned to address and to anticipate tomorrow’s water infrastructure needs becomes more like three-dimensional chess because each group holds different views of successes and failures.

“Applying the lessons learned to address and to anticipate tomorrow’s water infrastructure needs becomes more like three-dimensional chess because each group holds different views of successes and failures.”

I contend that exchanging ideas, providing thought leadership and technical expertise, and leading by example are not only roles, but the responsibility of all working in the water infrastructure world.

USSD is hosting its 2018 conference in Miami, Florida, April 30 – May 4. The conference theme is A Balancing Act: Dams, Levees and Ecosystems. Dams and levees have, and will continue to provide significant benefits to society. Many of our existing dams and levees are poised to provide additional benefit and solutions to some of our nation’s future infrastructure, environmental, social, and economic challenges. USSD invites all to engage with us as we take on more responsibility for developing sustainable water infrastructure for future generations. USSD also invites you to review the white paper prepared by the USSD Committee on Dam Decommissioning, in 2015, Guidelines for Dam Decommissioning Projects, found on the USSD website at www.ussdams.org (go to Resource Center, then Publications, then White Papers).
For more than 50 years, GZA has been involved in the inspection, investigation, engineering analysis, design, permitting and construction of more than 1,000 dams throughout the United States.

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New Dam Removal Analysis Guidelines for Sediment
In 2015, the USSD Committee on Dam Decommissioning published the Guidelines for Dam Decommissioning Projects. Chapter 5, Sediment Management, provided summary guidance on sediment-related impacts and sediment management alternatives. The USSD guidelines also mentioned that the Federal Advisory Committee on Water Information, Subcommittee on Sedimentation was preparing more detailed information. The new Dam Removal Analysis Guidelines for Sediment are now available at: http://bit.ly/2HEDBmg.

These new Guidelines have been developed to help match the level of data collection, analysis, and modeling to the risk of potential sediment impacts. These guidelines are based on concepts developed at workshops with national experts from government, universities, consultants, and non-governmental organizations, and from the benefit of numerous case studies from locations across the United States that had negligible to large reservoir sediment volumes.

The guidelines address dam removal and sediment management alternatives, evaluation of sediment-related impacts associated with those alternatives, and analysis uncertainty. The guidelines suggest an iterative analysis approach, starting with readily available information and revisiting or repeating analysis steps as more data become available. Once the sediment-related impacts are judged to be tolerable, then the guidelines recommend the development of a monitoring and adaptive management plan.

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Stephens to Receive ICOLD Honor

By Michael F. Rogers, ICOLD Vice President

During the ICOLD Board of Directors Meeting on January 27, 2018, in Paris, I was honored to nominate former USSD Executive Director Larry Stephens to receive the ICOLD Honorary Member Award, ICOLD’s highest recognition. USSD members are aware that after more than 30 years of service to USSD and ICOLD, Larry retired on August 31, 2016, and was named Executive Director Emeritus and Life Member by the USSD Board of Directors.

ICOLD will present the award to Larry during the ICOLD 2018 Congress meeting in Vienna, Austria, in July.

Recognizing that Larry is living on a limited retirement income and that the costs associated with attending the Congress could be more than $5,000, an organized Campaign for Support has been established for Larry. For this campaign, USSD has offered to collect contributions from any corporation or individual wishing to support Larry. USSD will then provide him with a check for 100% of the contributions.

If you would like to contribute to help defray Larry’s costs to attend ICOLD 2018 to receive this prestigious award, please send your check, payable to USSD (with “Larry’s fund” on the check) to USSD, 9975 Wadworth Parkway, Suite K-2, 145, Westminster, CO 80021.

Excitement Builds for Vienna 2018

A large delegation from USSD is expected to attend the 2018 Annual Meeting and 26th Congress, to be held July 1-7 in Vienna, Austria. To help us coordinate USSD participation involvement in ICOLD 2018, please notify USSD (sharon@ussdams.org) when you register for ICOLD 2018. For more information, visit www.icoldaustria2018.com.

The Congress Proceedings will include 16 papers submitted by USSD, and many of those were selected for oral presentation during the Congress. George Annandale will serve as the Chairman for Question 100, and David Bowles is the General Reporter for Question 101. Many USSD members will attend ICOLD committee meetings as the official USSD representative, or as observers.

One of the highlights of the week’s activities will be a special session with several presentations on the Oroville Dam spillway incident, organized by Mike Rogers. The session will include the results of the Oroville Dam Spillways Independent Forensic Investigation, presented by John France.

The 26th ICOLD Congress will focus on the following Questions:

Q100 - Reservoir sedimentation and sustainable development
Q101 - Safety and risk analysis
Q102 - Geology and dams
Q103 - Small dams and levees

The Austrian National Committee is organizing a Hydro Engineering Symposium in conjunction with the Congress, which will feature a Seminar on High Strength Steels in Hydropower Plants. In addition to outstanding technical content, the Congress and Annual Meeting will include numerous social/networking events, local tours, and post-meeting study tours.

Rogers Nominated for ICOLD President

Michael F. Rogers has been nominated to serve a three-year term as President of ICOLD. The election will take place during the 2018 Annual Meeting in Vienna. Rogers currently serves as an ICOLD Vice President. In a letter supporting the nomination, USSD President Dean Durkee wrote, “Mike has served USSD with great honor and accomplishment in his many years of service and we are confident that he will continue to serve the 100 countries of ICOLD with that same zeal, drive and determination for the profession of dam engineering.”

Rogers is Vice President, Global Dams Practice Leader for Stantec. He is a Past President of USSD and chaired the 2013 ICOLD Annual Meeting in Seattle.
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VISIT US AT BOOTH 409
History of Pathfinder Dam — People Were Tough Back Then

Note: Much of this section is excerpted from Reference 4 (Autobee, 1966), and is presented in italics. Additional text is either commentary by Larry Nuss, or information from other sources and referenced accordingly.

Introduction

Pathfinder Dam is a cyclopean masonry thick arch dam (dam height to base width of 0.45) completed in 1909. It was the second dam built by the United States Reclamation Service (USRS), now known as the Bureau of Reclamation (Reclamation). Pathfinder Dam was placed on the National Register of Historic Places in 1971 and is a Wyoming Historic Civil Engineering Landmark. The dam is 47 miles southeast of Casper, Wyoming on the North Platte River.

Pre-Construction

In 1841, a group of 70 settlers in covered wagons followed the Platte River on its south bank from Independence, Missouri, to its northern fork, the North Platte, continued through the South Pass, and north into Oregon. This route became the Oregon Trail, which in turn became the main overland artery from the east to the west coast of the United States until 1884, when railroads were built to carry settlers more swiftly and with less danger. The Mormon Trail in 1847 provided an alternate route on the north bank of the Platte River. Both trails, and several others that developed later, intersected and crossed the North Platte River at nearly the same spot near present-day Casper.

In 1842, John C. Fremont was sent by the United States Geological Survey (USGS) to explore southern Wyoming, especially the area around the North Platte and the emigrant trails, including the towns of Casper and Alcova. What Fremont found was a landscape cut by wind and water and full of hostile Indian tribes.

The desire to harness and maximize use of the waters of the North Platte River is as old as the Reclamation Service itself. During the dry summer season, the North Platte river system is not able to provide enough water for farmers in eastern Wyoming. In 1902, the North Platte, from its headwaters in northern Colorado through Wyoming and into Nebraska, was investigated for possible water storage sites. The North Platte Project, which includes Pathfinder Dam and Reservoir and Guernsey Dam and Reservoir in Wyoming, was developed for that purpose.

For irrigators in two states, access to water ended the cattleman’s monopoly of the land and raised agriculture to equal status in the region’s economy. When first proposed in 1902, the concept of drawing water from three states for use by two states was unheard of.

After author Washington Irving visited “the Great American Desert” in the 1830s, his romantic history, Adventures of Captain Bonneville, U.S.A., described cliffs of clay and sandstone “bearing the semblance of towers, churches, and fortified cities.” A niche cut by nature into a fortress of rock,
the dam nestles between the canyon walls three miles below the junction of the North Platte and Sweetwater Rivers. Ninety feet wide at the bottom and 200 feet wide at the top, the sides of the canyon’s upper 75 feet are nearly vertical, and the dark, perpendicular cliffs seem to be so close that they appear to be within reach of one another.

One story about explorer John C. Fremont and a moment of misfortune on the North Platte would inspire a later generation of American dam builders. An August 24, 1842, entry in his journal placed Fremont and his party passing through a “Big Cañon” on the North Platte, returning from an expedition to the Rocky Mountains. Making his way through the rapids by boat, he remembered, “we cleared rock after rock, and shot past fall after fall till the boat struck a concealed rock immediately at the foot of a fall, which whirled her over in an instant,” consequently losing his surveying instruments near the present dam site. Nearly sixty years later when it came time to christen the centerpiece of the North Platte Project, Fremont’s nickname, “The Pathfinder” was the winning choice.

In August 1903, under the direction of USRS engineer John E. Field, a diamond-drill camp was set where the two rivers flowed through a narrow granite canyon. The remote site was impossible to reach by either road or boat, subsequently slowing arrival of equipment at the canyon. Once the machinery did arrive, drill operations were conducted from a boat.

Foremost among the challenges was the location of the dam. A torturous forty-five miles from the largest nearby town, Casper, workers and material were always hard to come by. In 1905, a few months into construction, a Reclamation engineer lamented the “remoteness of the project, the poor roads, in places little better than trails.”

As one of the first projects by the USRS, they often operated by trial and error. Four months before Reclamation accepted bids on the dam, in February 1905, the USRS awarded a construction contract for the dam’s diversion tunnel to Kilpatrick Brothers and Collins Contracting Co. of Beatrice, Nebraska. On June 15, 1905, the USRS announced Bradbury & O’Gara of Denver won the right to build Pathfinder Dam. Later that month, the contractors went out to the dam site to find out what they had gotten themselves into. In two weeks, Bradbury & O’Gara withdrew their $364,940 bid, explaining by letter to Frederick Newell, “We have made very grave and insurmountable errors in our original figures.” Their price was 25 percent below the next lowest bidder and was much less than the work could be done for.

The story of the bungled bids had one more chapter to go that summer. The work was re-advertised and the bids opened again on August 16. This time, the lowest bidder, N.S. Sherman of Oklahoma City, came in with a proposal of $459,260. However, Sherman’s financial incapacity and lack of experience to construct a major dam was soon apparent. Their bid was rejected and the contract was awarded to Geddis and Seerie Stone Co. of Denver with the second lowest bid of $482,000. Geddis and Seerie’s most recent triumph was the just completed Lake Cheesman Dam. By the early autumn of 1905, many of those who built Cheesman picked up their tools and headed to Wyoming.
**Dam Design**

Geologic investigations were conducted from barges in October 1903 and consisted of two lines of four drill holes each. Five feet of sand, gravel and boulders were initially found, but granite was encountered at about 18 feet depth across the canyon [2].

The 214-foot tall masonry dam was the highest structure of its kind in the world at the time of its unveiling. The dam is a constant radius arch with a crest width of 10.9 feet, a base width of 94 feet, a crest length of 432 feet. Materials in the dam consist of 48.2 percent rock, 12.7 percent mortar, and 39.1 percent concrete [6]. The upper 30 feet of the dam is reinforced with steel on each face.

The dam was designed by George Y. Wisner and J. H. Quinton. The board of engineers approved the plans: A. P. Davis, H. N. Savage, A. J. Wiley, George Y. Wisner, Charles E. Wells, J. H. Quinton, and D. C. Henny. In 1904, George Wisner employed Edgar Wheeler to perform site-specific computations for the dam. The dam was designed by incorporating the 3-dimensional actions between the horizontal arches and vertical cantilevers to have equal deflections when carrying reservoir and temperature loads.

At a USRS Conference of Engineers in Ogden, Utah in September, 1903, George Y. Wisner, a Consulting Engineer to the USRS, presented a paper arguing that the Reclamation Service would have to build masonry dams of great height to provide ample storage in the often parched rivers and reservoirs of the west. Wisner emphasized the importance of accurate data to determine the stresses these structures would undergo. Wisner and Edgar T. Wheeler, a Los Angeles construction engineer, launched their investigations of the site in early 1905. In their report to the Board of Consulting Engineers of the USRS, both men emphasized the upper portion of the dam should receive extra protection to avoid cracking brought on by the region’s wild weather. Wisner and Wheeler won the board over with a design that incorporated efficiency, safety, and economy. Wisner preferred dams occupying narrow canyons where arch action of the dam could be taken into account [1].

Key points from the site investigation report are featured on the following page [8].

**Construction**

Excavating the diversion tunnel in the left abutment was the first construction activity. The 13-foot-wide, 10-foot-tall tunnel enters the canyon 90 feet upstream from the dam, is 480 feet long, passes the dam 85 feet behind the canyon wall, and exits 230 feet downstream from the dam. The tunnel served two purposes, to carry the river around the dam site during construction and subsequently perform as an outlet from the reservoir. The tunnel was worked from two headings as crews dug with hand tools for 11-and-a-half hours a shift. Fortunately, productivity increased after four electric and two steam drills replaced chisels and hammers.

In spite of falling rock and seeping water, foundation excavation began in January 1906. Fighting to reach bedrock, crews often had to cut through several feet of ice in temperatures that plunged to an extreme -29 °F below zero. Advancing despite the cold, progress halted March 25 when the river rose, breaking up the 3-foot-thick ice and flooding the dam site. There was no serious damage to men or machinery, but it was August 15 before the first stone of the dam was laid.

Excellent foundation was obtained 14 feet below the riverbed with an average depth of about 10 feet. A 4-inch-thick layer of “mudstone” was encountered and excavated from the foundation. The foundation was regarded as firm and sound and required some “roughening” to make it satisfactory [2].

The specifications required that the canyon walls be cut away until normal to the face of the dam and suitable, in the judgment of the engineer, for “solid and safe junction with the masonry.”

The canyon walls on the right abutment were excavated to sound rock generally encountering “rough planes normal to the face of the dam.” The right canyon wall presented no difficulties
Note: from *Investigation of Stresses in High Masonry Dams of Short Spans* [8]. Additional comments by Larry Nuss.

1. “The assumptions often make that a dam is an absolutely rigid structure and that the foundation on which it rests is perfectly elastic is by no means in accord with the materials used in construction, or with those in any foundation suitable for supporting such structures.”

2. “... a change in temperature of the structure may cause a wider range of pressures of the foundation than that arising from any possible change of water pressure on the face of the dam.”

3. “A foundation suitable and supporting a high man-made dam must be continuous for some distance up and downstream from the structure. The force of the dam will not be carried entirely by the material of the foundation immediately under the base, but will be distributed through the strata above and below the dam by bending action produced by the slight compression of the rock directly under and adjacent to the structure.”

4. “In the construction of a masonry or concrete dam a foundation course 40 to 50 feet in depth is usually put in for the entire length and width of the structure, which in a short span dam, when thoroughly set, becomes a rigid beam, slightly compressed under heavy loads.” (This is probably why the lower portion of Pathfinder Dam has smaller masonry blocks than the upper portions (see Figure 9).)

5. “These forces (thermal) have a tendency to give the crown of the arch at the crest of the dam a slight movement up and downstream, and since the lower portion of the structure is not subject to these changes of temperature, the movement produces bending moments in the vertical sections of the dam, which if not reinforced with steel may result in horizontal cracks in the downstream face and vertical cracks through the upper part of the structure.” (The dam has reinforcing steel in the upper portion of the dam.)

6. “… the upper portions of such a structure should be constructed when the temperature is below the normal for the location for which designed.” (Clearly the designers were aware that temperatures below the stress-free temperature cause materials to contract and resulting tensile stresses could crack the dam. So it was best to construct certain parts of the dam in the cooler times of the year. The dam was designed assuming 15 degrees above and 10 degrees below the stress-free temperature. It is not surprising that the dam is relatively free from cracks.)

7. The report shows profiles of Pathfinder Dam, the resultant of various load combinations, and the location of the kern (middle third) of the dam. Force resultants within the kern of the dam induce vertical compressive stresses on the face of the dam.

8. Material properties for the dam assumed in design of Pathfinder Dam included 153 lb/ft$^3$ density, 3,000,000 lb/in$^2$ modulus of elasticity, and 0.0000066 in/in/F coefficient of thermal expansion.

9. The report shows the deflection of the dam for various thermal and reservoir elevations considering cantilever and arch action.

10. The paper talks about placing reinforcing steel in the Salt River Dam (Theodore Roosevelt Dam near Phoenix, Arizona), Pathfinder Dam, and Shoshone Dam (Buffalo Bill Dam near Cody, Wyoming).

11. The report recommends putting thermophones (temperature recording) in the masonry and adjacent canyon walls to gather valuable information for other dams. (It is not known whether this was done.)

12. “The upper 15 feet of the dam has been assumed to offer no resistance as an arch, on account of the openings for waterways. This portion of the dam does, of course, act as an arch to a certain extent, but it was considered better to disregard it entirely, the error, if any, being on the side of safety.” (During site inspections in 2004, the top row of masonry on the left side of the dam is disbonded and horizontally displaced in the arch direction about 0.5 inches from the next row down.)

13. “A computation was made to determine the stresses in the dam considered as an arch, the resistance of vertical beams being disregarded. The arches alone would be able to resist the pressure of the water without developing excessive axial stresses.”

There was no foundation grouting during construction with a line of grouted drill holes, but there were seams in the left abutment that were washed clean and filled in with grout. There are no formed or foundation drains in the dam.

Figure 6. Masonry Progress, April 27, 1908.
in attaining satisfactory geometry. With few exceptions, when the seamy, loose, and disintegrated rock had been removed, the remaining surface was sound rock in a plane normal to the dam face.

The left abutment wall of the canyon presented more difficulty with a natural trend of the seams angled about 30 degrees outside a radial line to the dam requiring “special work to obtain a suitable contact between the masonry and the abutment.” A vertical seam was over-excavated to a depth of about 30 feet by softening with water and excavating with a small scraper. The seam was further excavated using a 1-inch pipe connected to a steam pump and pressure was applied to the seam. The remaining material was scraped out. This seam was later grouted at the surface and soft cement was tamped into place to fill the bond at the rock contact [2]. As a result, a great amount of unsound rock was reportedly removed from the canyon walls causing a proportionate increase in the amount of masonry required for the dam. Along with rock and gravel excavation, several feet of ice had to be removed every morning (see Figure 7).

Acquiring the stone for the dam was easier logistically, but this job, too, had its own inconveniences. Hard, coarse-grained granite was quarried within a quarter-mile of the dam. Pieces of rock forty feet square were first blown out of the canyon and split into smaller blocks averaging eight to 10 tons. After the blocks were dressed and drenched with water, the granite squares were placed into position by cables. The dam had to be as imperious as possible, meaning all voids filled and no leaks allowed. This was achieved with up to 10 inches of concrete mortar placed between the blocks. The best results came from “rich” concrete mixed very wet in order to fill every crack. Wet concrete was also much easier to work than a slightly stiffer mixture. This method also had economics behind it; use of more stone meant the contractor could use fewer barrels of the expensive cement. Before placing the mortar bed for a stone, the area was swept and wet with a hose, followed by a lot of prying and lifting by the masons to position the stone properly.

Freighting outfits of all kinds and sizes were used to deliver cement 45 miles from Casper to the site from sheep wagons drawn by two horses, mules carrying 24 sacks of cement, to 22-horse teams drawing five wagons coupled together hauling 327 sacks weighing 31,000 lbs (see Figure 10). Local Newspaperman Alfred J. Mokler recalled the fastest delivery took three days, while the longest lasted a staggering 76 days over low valleys and high hills in all kinds of weather. [These people were tough!] In spite of it being rough and remote, North Platte’s concrete plant was up-to-date by the standards of the first decade of the new century. Estimated to cost over $60,000, the plant’s machinery included 10 guy derricks with 60-foot masts, 55-foot booms, two cableways spanning 350 feet, mixers, and a concrete mixing house designed so that one man could handle over 700 sacks of cement in an eight-hour shift while a second man mixed an equal amount into mortar and concrete at the same time.

The first stone was laid August 15, 1906 in the southeast corner of the foundation. Masonry work continued during the season until cold weather shutdown in late November. Construction resumed in March batched at a plant on the left side of the dam. There was no artificial cooling or grouting of the dam body. Concrete was stored in a room capable of holding about 1000 sacks (see Figure 8). Each 14-cubic foot batch of concrete contained 3 sacks of cement [1].

Cars containing mortar or concrete were run out under the cableways, picked up, and delivered to the derricks. Whenever possible, concrete was dumped directly from the

Figure 8. Cement bags, May 12, 1908.
One person handling the cement and another operating the mixers could mix 800 sacks of cement in an 8-hour day for about 225 cubic yards of masonry per day. The capacity of the mixing plant was about 250 cubic yards per 8-hour day, but the cableways could only handle 200 cubic yards. The maximum monthly quantity of masonry laid was 5,040 cubic yards (163 cubic yards per day) in August 1908.

It was necessary to lay masonry sufficiently slow so that the work would set and settle before being carried too high, otherwise cracks would appear.

According to the specifications, the main body of the dam was to be constructed of broken cyclopean rubble laid so as to break joints and thoroughly bond the work in all directions. Each stone was laid in a heavy bed of mortar and the side joints not less than 6 inches thick rammed with concrete into place.

When the dam was leveled up, a course of stones were laid on each face of the dam with a 2 to 1 mortar mix on the upstream side and a 2.5 to 1 mix on the downstream face. Backing stone varying in size from 1 to 5 cubic yards were set as thickly as possible between the face coarses. Stone chunks were places where there was no room for a fair sized stone. These stones were always placed in a 2.5 to 1 mortar mix and vertical joints filled with concrete.

The foundation was broomed over with thick cement grout.

All the stone used in the dam was obtained from three different quarries each within 1/4-mile from the dam.

Post-Construction

There were no major mishaps during Pathfinder’s long construction period, but tragedy struck after its completion. On the evening of February 9, 1912, five men fell 186 feet to their deaths when an overhead cable snapped. The men were installing a concrete ladder on the canyon wall. The graves of two of those victims remain on a barren shelf overlooking the dam.

In 1949, Kimball Brothers Co. of Council Bluffs, Iowa was awarded the contract to install an elevator on the downstream face of the dam. During the planning of the elevator, drill holes loaded with live dynamite were found on the downstream face of Pathfinder Dam [7]. This was the dynamite that was placed in 1909 as a possible safe gap measure to blow the top of the dam during a large flood, produce a 10-foot by 20-foot channel, and save the emergency dike on the right abutment. Five holes had been drilled on each face of the dam and the downstream holes were loaded with dynamite. Fortunately, flood waters receded, the operation halted, and the dam did not have to be blown. The holes were covered with mortar, but the dynamite was left in place. The 40-year-old dynamite was neutralized with solvent and removed along with the primers.

Concluding Remarks

Like the man who inspired its name, the Pathfinder Dam led the way for new ideas. For Reclamation, Pathfinder encouraged the build big philosophy and the adaptive attitude necessary to finish the early Federal dams. And despite early bad press, the project survives. The project also brought about a shift in the local economy. While conditions at first were rugged for builders and those who initially broke the soil, the rewards continue to the present day.

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2018 Election Results

In recent online balloting, four members were elected to three-year terms on the USSD Board of Directors and will assume office following the 2018 Annual Conference. Denise Bunte-Bisnett and John D. Rice were elected to their second terms; and Rodney E. Eisenbraun and Del A. Shannon were elected to their first terms.

Denise Bunte Bisnett, Principal Engineer, South Carolina Public Service Authority (Santee Cooper). Ms. Bisnett has more than 30 years of experience working in public power with a focus on dam safety and environmental stewardship. She is an active member of USSD, currently serves as Secretary/Treasurer of the Board of Directors, and previously served as the Chair of the USSD Committee on the Environment and Sustainability.

Rodney W. Eisenbraun, Principal, RJH Consultants, Inc. Mr. Eisenbraun has over 36 years of experience in dam safety engineering including hydrologic, hydraulic, structural, geotechnical, and hydro-mechanical engineering. His clients have included international governments, federal agencies, state governments, local municipalities, water and flood control agencies, investor owned utilities, mines, and agricultural owners. Rod has been an active member of USSD for many years and chaired Planning Committee for the 2016 USSD Conference.

John D. Rice, Associate Professor, Utah State University. He spent 16 years with Woodward-Clyde Consultants and Kleinfelder, where was responsible for the investigation, assessment, and design of a number of levee seepage and stability mitigation projects. In 2004 he started his Ph.D. studies at Virginia Tech where he studied the long-term performance of seepage barriers in dams. During his Ph.D. studies he was awarded the 2006 USSD Scholarship. At Utah State University he performs research in the areas of reliability-based analyses of internal erosion potential and laboratory modeling of internal erosion mechanisms.

Del A. Shannon, Business Development Manager-Heavy Civil, Barnard Construction Company. Mr. Shannon has nearly 30 years of experience in the civil, geotechnical, and environmental engineering fields, with an emphasis on the design, construction and safety of embankment and concrete dams and levees. In recent years he has focused his efforts on forming project teams that engage all key members who bring their unique expertise to complex and challenging projects. He has served on several USSD committees, and the ICOLD Concrete Dams Committee.

News of Members

Thomas Brown has retired from USDA, Natural Resources Conservation Service.

William Fiedler recently retired from the Bureau of Reclamation, after 42 years of service. He is a part-time senior technical advisor for dam safety/risk in the HDR Denver office.

GZA, a nationally recognized leading environmental and geotechnical consulting firm with corporate headquarters in Norwood, Massachusetts, has announced the acquisition of Civil Dynamics (CD), a New Jersey-based consulting firm recognized as a regional leader in dam engineering. The acquisition significantly strengthens the company’s dam and water resource capabilities in the New York-New Jersey-Pennsylvania region, and as well as its experience with dam engineering inspections and projects.

Warren Paul recently retired from AECOM.

Phoebe Percell, P.E., has been named senior technical advisor for dam and civil works for HDR, based in the firm’s Denver office. In her new position, Percell will help lead the expansion of HDR’s structural engineering analysis and design capabilities with a focus on concrete dams, spillways and outlet works.

RIZZO Associates, Inc. is now RIZZO International, Inc. Transfer of ownership was recently completed from Paul Rizzo to his daughters Rachelle Rizzo, who will serve as President; and Mara Rizzo McClain. Michael Edwards is Chief Operating Officer/Senior Vice President of Engineering.
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